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Effect of soil and foliar application of multimicronutrient mixture on growth, yield and nutrient content of drilled paddy

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Abstract

The field experiments were conducted at Agriculture Research Station, Anand Agricultural University, Derol, Panchmahal, Gujarat, India during *kharif* seasons (2021, 2022 and 2023). Thirteen treatments for soil and foliar application of multimicronutrient were studied in randomized block (RBD) with four replications to study the “effect of soil and foliar application of multimicronutrient mixture on growth, yield and nutrient content of drilled paddy”. Result of field experimentations revealed that, apply either treatment T₄:1.0% foliar spray (100 g/10 lit water) of Government notified multi micro nutrient mixture Grade II (Fe: 6.0, Mn: 1.0, Zn: 4.0, Cu: 0.3 and B:0.5%) OR T₁₁: 0.5% foliar spray of FeSO₄ (50 g/10 lit water) at 20, 40 and 60 days after sowing along with 50 kg N/ha, of which 25 kg N/ha and 25 kg P₂O₅ /ha as basal and 25 kg N /ha at 30 days after sowing was recorded higher growth and yield attributes, yield, gross returns, net returns, benefit cost ratio in comparison to rest of treatments. Soil and foliar application of multi-micronutrient mixture grade did not significantly affect the soil chemical properties like pH, EC, organic carbon, soil available P₂O₅, K₂O and S after harvest and in significant differences for available iron, manganese, zinc and copper content of soil due to different treatments, significantly affect the leaf analysis after one week of third foliar spray. The results revealed that significant differences for iron and zinc content of leaf due to different treatments while, manganese and copper contents of leaf did not significantly effect of different treatments. The results also revealed that significant differences for sulphur, iron and zinc content of grain and straw due to different treatments while, manganese and copper contents of grain and straw did not significantly effect of different treatments and significantly affect the active Fe content from the plant at 30 DAS analysis.

Keywords: Drilled paddy, soil and foliar application and multimicronutrient

Introduction

Rice is the staple food of the tribal people of middle Gujarat. In Gujarat unirrigated rice is an cultivated area of 1.57 lakh hectares and production of 3.10 lakh tones with productivity of 1980 kg/ha (Annon., 2023) ^[3]. In Gujarat, Panchmahals district un irrigated rice is an cultivated area of 0.17 lakh hectares and production of 0.23 lakh tones with productivity of 1336 kg/ha (Annon.2023) ^[3]. In Gujarat, Iron nutrient is critical for chlorophyll formation, photosynthesis, plant enzyme activation and oxygen carrier in nitrogen fixation (Ali, 2012) ^[1]. About 40% of the soils of India are deficient in available Zn, especially in states like Gujarat, Bihar and Madhya Pradesh (Kumar *et al.* 2019) ^[11]. Though Gujarat has considerable area of upland rice its production is very low. Singh *et al.* (2005) ^[15] reported lower yield in DSR than TPR principally due to poor crop stand, high percentage of panicle sterility, higher weed and root-knot nematode infestation. In direct seeding, availability of several nutrients including N, P, S and micronutrients such as Zn and Fe, is likely to be a constraint (Ponnamperuma, 1972) ^[14]. None of the less, farmers are inclining to adopt DSR and the area under DSR is increasing as it is more productive and profitable to compensate the production costs. In view of this, field trial was carried out on integrated nutrient management of major nutrients viz., N, P and K with along with soil application of Fe or/and Zn or foliar application of Fe or/ and Zn to evaluate the performance of various nutrient. It has been reported that application of Zn at different rates and frequencies influenced the productivity of maize - wheat cropping system in typichaplustepts soil of Gujarat, India (Kumar *et al.*, 2022) ^[12]. Therefore essential to provide an effective multi

micronutrient management for drilled paddy. Keeping above in view a field experiment was conducted to find out the “effect of soil and foliar application of multimicronutrient mixture on growth, yield and nutrient content of drilled paddy”.

Materials and Methods

The Field experiment was carried out to study the “effect of soil and foliar application of multimicronutrient mixture on growth, yield and nutrient content of drilled paddy”. The experiment was conducted at Agriculture Research Station, Anand Agricultural University, Derol, Dist: Panchmahals, Gujarat, India during *kharif* seasons of 2021, 2022 and 2023. The plot size was 3.6 x 5.0 m. The treatment details are given in table a. The soil of the experimental field was sandy loam in texture having low in organic carbon and nitrogen, higher in available phosphorus and medium in potassium Initial physic-chemical properties of soil status was analysed and given in table b. Different grade of micronutrient mixture used in experiment are given in table-c. Soil test value application Fe@15 kg/ha for basal. The drilled paddy variety AAUDR 1 was used in the experiment as a test crop. All the recommended agronomic practices were followed for raising the crop during all the years of experimentation. The observations on growth and yield attributes was recorded. Soil analysis at initial and after harvest of crop was done to assess the nutrient content, leaf analysis after one week of third foliar spray, grain and straw analysis at harvest and analyze the active iron content from the plant at 30 DAS. Data was analyzed statistically using Fisher’s analysis of variance technique and treatment means were compared using least significant difference test at 5% level of probability.

Table A: Treatment details

Sr. No.	Treatments	Dose kg/ha or (%)	Application Time
T ₁	RDF	50:25:00 (NPK kg/ha)	Basal and 30 DAS
T ₂	RDF + MM Grade V 20 kg/ha	20 kg/ha	Basal
T ₃	RDF+ MM Grade I foliar spray	1.0%	Three spray (20, 40 & 60 DAS)
T ₄	RDF + MM Grade II foliar spray	1.0%	
T ₅	RDF+ MM Grade III foliar spray	1.0%	
T ₆	RDF+ MM Grade IV foliar spray	1.0%	
T ₇	RDF + MM Grade V + MM Grade I foliar spray	1.0%	
T ₈	RDF + MM Grade V + MM Grade II foliar spray	1.0%	
T ₉	RDF + MM Grade V + MM Grade III foliar spray	1.0%	
T ₁₀	RDF + MM Grade V + MM Grade IV foliar spray	1.0%	
T ₁₁	RDF + FeSO ₄ foliar spray	0.5%	
T ₁₂	RDF + FeSO ₄ foliar spray	1.0%	
T ₁₃	RDF + Micronutrient as per STV	Fe @ 15 kg/ha	Basal

Note: Soil application of 10 t FYM/ha applied in all plots at the time of land preparation

Table B: Initial soil status

pH (1:2.5)	7.4
EC (1:2.5) (dS/m)	0.372
OC (%)	0.51
Av. P ₂ O ₅ (kg/ha)	65.3
Av. K ₂ O (kg/ha)	163.2
Av. S (mg/kg)	3.49
Av. Fe (mg/kg)	5.79
Av. Mn (mg/kg)	4.63
Av. Zn (mg/kg)	2.62
Av. Cu (mg/kg)	1.55

Initial micronutrient analysis for treatment T₁₃ (STV)

Initial (Available)	DTPA-Fe (ppm)	DTPA-Mn (ppm)	DTPA-Zn (ppm)	DTPA-Cu(ppm)
	5.81(Deficient)	5.23	2.68	1.49
Application for STV	FeSO ₄ @ 15 (kg /ha)	-	-	-

Table C: Micronutrient content in different type of multi micronutrient grade

Grade	Amount of micronutrient (%)				
	Fe	Mn	Zn	Cu	B
For the spray					
Multi micronutrient Grade I (General grade)	2.0	0.5	4.0	0.3	0.5
Multi micronutrient Grade II (for iron deficiency)	6.0	1.0	4.0	0.3	0.5
Multi micronutrient Grade III (for zinc deficiency)	2.0	0.5	8.0	0.5	0.5
Multi micronutrient Grade IV (for zinc and iron deficiency)	4.0	1.0	6.0	0.5	0.5
For soil application					
Multi micronutrient Grade V (General grade)	2.0	0.5	5.0	0.2	0.2

FYM analysis

Total contents (as per dry wt. basis)							
Fe	Mn	Zn	Cu	S	P	K	N
(mg/kg)				(%)			
12623	299	91.58	38.71	0.39	0.83	0.67	0.85

Results and Discussion

The pooled results of three years of experimental findings on the effect of soil and foliar application of a multi-micronutrient mixture on the growth, yield and nutrient content of drilled paddy have been discussed under following heads.

Effect on growth and yield attributes

Application of treatment T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40 and 60 DAS) resulted significantly higher plant height at 40 DAS. Treatments T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS) and T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS) were statistically at par with treatment T₁₂. Similar result was observed by Anitha and Kadalli (2019)^[4] that application of soil micronutrient mixture and foliar micronutrient mixture gave higher plant height in maize. The treatments had no significant effect on plant height at harvest. Number of effective tillers per meter of row length and test weight (g) were significantly higher with the application of Treatment T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS). This was statistically similar to treatments T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS) and T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40 and 60 DAS). Treatment T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS) recorded the highest number of grains per panicle and was statistically at par with Treatments T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS) and T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40 and 60 DAS). Treatment T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40 and 60 DAS) recorded significantly greater panicle length compared to the rest of the treatments and was statistically at par with treatments T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS) and T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS). Treatment T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS) recorded the highest panicle weight and was

statistically at par with Treatments T₄ (RDF + MM Grade II @ 1.0% foliar spray) and T₁₂ (RDF + 1.0% FeSO₄ foliar spray). According to Hatwar *et al.* (2003)^[8], the enhancement of growth parameters through micronutrient application is likely linked to stimulated photosynthetic and metabolic processes. These intensified activities increase the production of essential plant metabolites, which are fundamental to the mechanisms of cell division and elongation. Treatment T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS) recorded the highest grain and straw yields (2016 and 3584 kg/ha, respectively) and was statistically at par with Treatments T₁₁ (RDF + 0.5% FeSO₄ foliar spray) and T₁₂ (RDF + 1.0% FeSO₄ foliar spray), both applied at 20, 40 and 60 DAS. Chandrakumar *et al.* (2004)^[5], Singh and Ram (2005)^[16] and Esfahani *et al.* (2014)^[7] were noted that applying Iron (Fe) and Zinc (Zn) boosts wheat and rice yields across diverse agro-climatic environments. Patel and Singh (2010)^[13] were also observed that the advantages of multi-micronutrient application on the synergistic effect of balanced nutrition, which improved crop growth and increases productivity.

Effect on soil nutrient status

Soil and foliar application of multimicronutrient mixture grade did not significantly affect the soil chemical properties such as pH, EC, organic carbon, soil available P₂O₅, K₂O and Sulphur. Treatment T₇ (RDF + MM Grade V @ 20 kg/ha + MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS) recorded significantly higher available iron content and was statistically at par with T₁₀ (RDF + MM Grade V @ 20 kg/ha + MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS), T₈ (RDF + MM Grade V @ 20 kg/ha + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS) and T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS). Treatment T₁₀ (RDF + MM Grade V @ 20 kg/ha along with MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS) resulted in the highest manganese availability, which was statistically comparable to T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS) and T₉ (RDF + MM Grade V @ 20 kg/ha + MM Grade III @ 1.0% foliar spray at the same intervals). Application of treatment T₁₁ (RDF+0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS) resulted in higher available zinc content in the soil after the harvest of rice and was statistically at par with T₁₀ (RDF + MM Grade V @ 20 kg/ha + MM Grade IV @ 1.0% foliar spray), T₉ (RDF + MM Grade V @ 20 kg/ha + MM Grade III @ 1.0% foliar spray), T₈ (RDF + MM Grade V @ 20 kg/ha + MM Grade II @ 1.0% foliar spray) and T₇ (RDF + MM Grade V @ 20 kg/ha + MM Grade I @ 1.0% foliar spray), all applied at 20, 40 and 60 DAS. Application of treatment T₁₀ (RDF + MM Grade V @ 20 kg/ha + MM Grade IV @ 1.0% foliar spray) resulted in higher available copper content in the soil and was statistically comparable with T₁₁ (RDF + 0.5% FeSO₄ foliar spray), T₉ (RDF + MM Grade V @ 20 kg/ha + MM Grade III @ 1.0% foliar spray) and T₈ (RDF + MM Grade V @ 20 kg/ha + MM Grade II @ 1.0% foliar spray), all applied at 20, 40 and 60 DAS.

Effect on nutrient content in leaf

Soil and foliar application of multi-micronutrient mixture grades significantly affected the leaf nutrient content one week after the third foliar spray. Treatment T₅ (RDF + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS) recorded significantly higher iron content and was statistically at par with T₆ (RDF + MM Grade IV @ 1.0% foliar spray), T₁₂ (RDF + 1.0% FeSO₄ foliar spray), T₉ (RDF + MM Grade V @ 20 kg/ha + MM Grade III @ 1.0% foliar spray), T₁₁ (RDF + 0.5% FeSO₄ foliar spray), T₈

(RDF + MM Grade V @ 20 kg/ha + MM Grade II @ 1.0% foliar spray), T₄ (RDF + MM Grade II @ 1.0% foliar spray) and T₁₃ (RDF + micronutrients as per STV), all applied at 20, 40 and 60 DAS. Zinc content in the leaf was significantly higher in Treatment T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS) and was statistically at par with Treatments T₅ (RDF + MM Grade III @ 1.0% foliar spray), T₆ (RDF + MM Grade IV @ 1.0% foliar spray), T₇ (RDF + MM Grade V @ 20 kg/ha + MM Grade I @ 1.0% foliar spray), T₈ (RDF + MM Grade V @ 20 kg/ha + MM Grade II @ 1.0% foliar spray), T₉ (RDF + MM Grade V @ 20 kg/ha + MM Grade III @ 1.0% foliar spray) and T₁₀ (RDF + MM Grade V @ 20 kg/ha + MM Grade IV @ 1.0% foliar spray), all applied at 20, 40 and 60 DAS. Manganese and copper contents in the leaf were not significantly affected by different treatments in the pooled results.

Effect on nutrient content in grain and straw

Soil and foliar application of multimicronutrient mixture grades significantly affected the nutrient content of grain and straw. Treatment T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40, and 60 DAS) recorded the highest sulphur content and was statistically at par with treatments T₃ (RDF+ MM grade I @ 1.0% foliar spray at 20, 40 and 60 DAS), T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS), T₆ (RDF+ MM grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS), T₅ (RDF+ MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS), T₈ (RDF + MM Grade V@ 20 kg/ha + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS), T₉ (RDF + MM Grade V@ 20 kg/ha + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS), T₁₀ (RDF + MM Grade V@ 20 kg/ha + MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS), T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS), T₇ (RDF + MM Grade V@ 20 kg/ha + MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS), T₁₃ (RDF + Micronutrient as per STV) and T₂ (RDF + MM Grade V@ 20 kg/ha), T₃ (RDF+ MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS). Application of treatment T₁₃ (RDF + micronutrients as per STV) recorded the highest iron content in the grain which was statistically at par with treatment T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40 and 60 DAS) and T₉ (RDF + MM Grade V@ 20 kg/ha + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS). For zinc content in grain, treatment T₄ (RDF + MM Grade II @ 1.0% foliar spray) recorded significantly higher values and was statistically on par with T₈ (RDF + MM Grade V@ 20 kg/ha + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS). Sulphur content in the straw was significantly highest in Treatment T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS) and it was statistically similar to T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40 and 60 DAS), T₄, T₅ (RDF+ MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS), T₁₀ (RDF + MM Grade V@ 20 kg/ha + MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS), T₁₃ (RDF + Micronutrient as per STV), T₂ (RDF + MM Grade V@ 20 kg/ha), T₃ (RDF+ MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS), T₇ (RDF + MM Grade V@ 20 kg/ha + MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS) and T₆ (RDF+ MM grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS). Iron content in straw, T₅ (RDF + MM Grade III @ 1.0% foliar spray) recorded the highest values and was statistically similar with treatments T₆ (RDF+ MM grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS), T₈ (RDF + MM Grade V@ 20 kg/ha + MM Grade II @

1.0% foliar spray at 20, 40 and 60 DAS), T₉ (RDF + MM Grade V@ 20 kg/ha + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS), T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS), T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40 and 60 DAS), T₂ (RDF + MM Grade V@ 20 kg/ha) and T₁ (RDF (50:25:00 NPK kg/ha). For zinc content in straw, T₄ (RDF + MM Grade II @ 1.0% foliar spray) showed significantly higher content and was statistically at par with all other treatments except T₁₃ (RDF + Micronutrient as per STV). In contrast, manganese and copper contents in both grain and straw were not significantly affected by any of the treatments in the pooled results.

Effect on active iron content in plant at 30 DAS

The active iron content in plants at 30 DAS was influenced by soil and foliar application of multi-micronutrient mixture grades. The pooled data showed variations among treatments, with values ranging from 15.5 to 19.5 mg/kg. The highest active Fe content (19.5 mg/kg) was recorded in treatments T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40, and 60 DAS) and T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40, and 60 DAS) being at par with T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40, and 60 DAS) and T₈ (RDF + MM Grade V@ 20 kg/ha + MM Grade II

@ 1.0% foliar spray at 20, 40 and 60 DAS). The lowest active Fe content was observed in T₁ (RDF alone), which recorded only 0.042 mg/kg. Similar findings was reported by Chakraborty *et al.* (2012) [6] on peach cultivar and they observed that leaf mineral status (active iron/Fe²⁺) was improved with the application of different iron sources, application of Fe sulphate found to be the best iron source for foliar application. This might be attributed to more penetration capacity of this iron source across the leaf epidermis possibly due to lesser molecular weight than other two iron sources (Fe-EDTA and Fe-citrate).

Economics

The economics of various treatments, treatment T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40 and 60 DAS), T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS) and T₁₂ (RDF + 1.0% FeSO₄ foliar spray at 20, 40 and 60 DAS) registered the net return of Rs 28822/hectare, Rs 26148/hectare and Rs 26009/hectare with BCR 1.98 and 1.76 and 1.88, respectively. Similar result was found by Anitha and Kadalli (2019) [4] that application of soil micronutrient mixture with foliar micronutrient mixture gave highest gross return and Net return.

Table 1: Growth and yield parameters as influenced by different treatments in drilled paddy

Treatment	Plant height (cm) at 40 DAS	Plant height (cm) at harvest	No. of effective tiller (m/row length)	No. of grain/panicles	Panicle length (cm)	Panicle weight (g)	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
T ₁ : RDF (50:25:00 NPK kg/ha)	59.6 ^e	98.5	50.1 ^d	77.4 ^f	21.6 ^d	2.42 ^f	24.4 ^e	1036 ^e	2067 ^f
T ₂ : RDF + MM Grade V@ 20 kg/ha	60.9 ^{cde}	98.8	55.4 ^{cd}	89.9 ^{cde}	22.1 ^d	2.47 ^f	25.4 ^{abcd}	1244 ^{de}	2156 ^{ef}
T ₃ : RDF + MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	63.8 ^{abc}	99.7	58.1 ^c	96.7 ^{bcd}	22.6 ^{abcd}	2.75 ^{abcde}	25.6 ^{abcd}	1346 ^{cde}	2355 ^{def}
T ₄ : RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	64.4 ^{ab}	103.4	72.4 ^{ab}	120.4 ^a	23.6 ^{ab}	2.90 ^{abc}	25.9 ^{ab}	2016 ^a	3584 ^a
T ₅ : RDF + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	62.2 ^{abcde}	104.0	57.5 ^c	96.4 ^{bcd}	21.7 ^d	2.66 ^{cdef}	25.2 ^{bcde}	1608 ^{bc}	2870 ^{bcd}
T ₆ : RDF + MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	61.2 ^{bcde}	98.5	55.5 ^{cd}	82.9 ^{ef}	22.0 ^d	2.60 ^{ef}	24.9 ^{cde}	1284 ^{cde}	2408 ^{def}
T ₇ : RDF + MM Grade V@ 20 kg/ha + MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	60.3 ^{de}	101.8	59.8 ^c	101.8 ^{bc}	22.7 ^{abcd}	2.86 ^{abcd}	25.5 ^{abcd}	1458 ^{cd}	2597 ^{def}
T ₈ : RDF + MM Grade V@ 20 kg/ha + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	63.2 ^{abcd}	102.0	55.1 ^{cd}	96.0 ^{cd}	22.5 ^{bcd}	2.63 ^{def}	25.1 ^{bcde}	1405 ^{cd}	2515 ^{def}
T ₉ : RDF + MM Grade V@ 20 kg/ha + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	61.8 ^{bcde}	101.8	54.2 ^{cd}	87.1 ^{def}	21.5 ^d	2.57 ^{ef}	24.8 ^{de}	1252 ^{de}	2108 ^f
T ₁₀ : RDF + MM Grade V@ 20 kg/ha + MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	62.6 ^{abcde}	101.3	58.8 ^c	96.7 ^{bcd}	22.3 ^{cd}	2.73 ^{bcde}	25.0 ^{bcde}	1301 ^{cde}	2345 ^{def}
T ₁₁ : RDF + 0.5% FeSO ₄ foliar spray at 20, 40 and 60 DAS	63.8 ^{abc}	104.9	76.6 ^a	120.2 ^a	23.4 ^{abc}	3.00 ^a	26.3 ^a	1937 ^{ab}	3471 ^{ab}
T ₁₂ : RDF + 1.0% FeSO ₄ foliar spray at 20, 40 and 60 DAS	65.4 ^a	104.2	70.4 ^b	109.9 ^{ab}	23.8 ^a	2.98 ^{ab}	25.8 ^{abc}	1859 ^{ab}	3254 ^{abc}
T ₁₃ : RDF + Micronutrient as per STV	63.0 ^{abcd}	103.4	56.6 ^c	92.6 ^{cde}	22.0 ^d	2.65 ^{cdef}	25.0 ^{bcde}	1340 ^{cde}	2720 ^{cde}
S.Em. ±	1.02	2.08	1.81	4.07	0.37	0.08	0.28	99	187
CD at 5%	Sig.	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
Y S.Em. ±	0.48	1.06	0.90	1.32	0.18	0.04	0.14	17	29
CD at 5%	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	NS	Sig.	Sig.
Y x T S.Em. ±	1.72	3.82	3.25	4.75	0.64	0.13	0.52	61	103
CD at 5%	NS	NS	NS	Sig.	NS	NS	NS	Sig.	Sig.
CV%	5.53	7.52	10.83	9.74	5.73	9.47	4.11	8.30	7.76

Treatment mean with the letter/letters in common are not significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance.

Table 2: Effect of soil chemical properties as influenced by different treatments in drilled paddy

Treatment	pH (1:2.5)	EC (dS/m)	OC (%)	Available P ₂ O ₅ (kg/ha)	Available K ₂ O (kg/ha)	Available S (mg/kg)	Available Fe (mg/kg)	Available Mn (mg/kg)	Available Zn (mg/kg)	Available Cu (mg/kg)
T ₁ : RDF (50:25:00 NPK kg/ha)	7.5	0.365	0.57	68.1	155.5	3.45	6.25 ^e	4.06 ^e	2.57 ^e	1.46 ^f
T ₂ : RDF + MM Grade V@ 20 kg/ha	7.5	0.371	0.59	69.1	150.4	3.50	7.13 ^{abc}	4.95 ^{abcd}	3.20 ^b	1.49 ^{ef}
T ₃ : RDF+ MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	7.5	0.376	0.60	70.2	152.8	3.56	6.43 ^{de}	4.26 ^e	2.92 ^{cd}	1.48 ^{ef}
T ₄ : RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	7.4	0.371	0.56	69.8	149.7	3.41	6.61 ^{cde}	4.42 ^{cde}	2.91 ^{cd}	1.56 ^{bcde}
T ₅ : RDF+ MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	7.5	0.364	0.55	68.7	149.4	3.39	6.46 ^{de}	4.25 ^e	2.87 ^{cd}	1.49 ^{def}
T ₆ : RDF+ MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	7.5	0.361	0.58	71.5	150.0	3.46	6.20 ^e	4.37 ^{de}	2.74 ^{de}	1.45 ^f
T ₇ : RDF + MM Grade V@ 20 kg/ha + MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	7.5	0.359	0.57	67.5	145.9	3.43	7.49 ^a	5.00 ^{abc}	3.63 ^a	1.62 ^{abc}
T ₈ : RDF + MM Grade V@ 20 kg/ha + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	7.5	0.371	0.53	68.3	150.9	3.46	7.32 ^{ab}	5.00 ^{abc}	3.58 ^a	1.62 ^{ab}
T ₉ : RDF + MM Grade V@ 20 kg/ha + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	7.5	0.369	0.57	71.1	148.3	3.36	7.33 ^{ab}	5.26 ^a	3.52 ^a	1.63 ^{ab}
T ₁₀ : RDF + MM Grade V@ 20 kg/ha + MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	7.5	0.369	0.58	70.5	153.0	3.42	7.42 ^a	5.33 ^a	3.51 ^a	1.66 ^a
T ₁₁ : RDF + 0.5% FeSO ₄ foliar spray at 20, 40 and 60 DAS	7.5	0.368	0.56	69.6	151.1	3.63	7.30 ^{ab}	5.16 ^{ab}	3.62 ^a	1.63 ^{ab}
T ₁₂ : RDF + 1.0% FeSO ₄ foliar spray at 20, 40 and 60 DAS	7.4	0.361	0.54	74.0	153.2	3.47	6.93 ^{abcd}	4.55 ^{bcde}	2.91 ^{cd}	1.58 ^{abcd}
T ₁₃ : RDF + Micronutrient as per STV	7.5	0.352	0.57	66.2	147.9	3.59	6.85 ^{bcd}	4.06 ^e	3.07 ^{bc}	1.53 ^{cdef}
S.Em. ±	0.04	0.006	0.02	1.60	2.46	0.08	0.17	0.19	0.07	0.03
CD at 5%	NS	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.	Sig.
Y S.Em. ±	0.01	0.002	0.01	0.78	1.17	0.03	0.08	0.05	0.03	0.01
CD at 5%	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
Y x T S.Em. ±	0.05	0.008	0.03	2.80	4.21	0.13	0.30	0.20	0.10	0.05
CD at 5%	NS	0.02	NS	NS	NS	NS	NS	Sig.	Sig.	NS
CV%	1.85	4.31	10.31	8.04	5.59	7.34	8.77	8.34	6.38	6.43

Treatment mean with the letter/letters in common are not significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance.

Table 3: Effect of Grain and straw analysis at harvest as influenced by different treatments in drilled paddy

Treatment	Grain					Straw				
	S content (%)	Fe content (mg/kg)	Mn content (mg/kg)	Zn content (mg/kg)	Cu content (mg/kg)	S content (%)	Fe content (mg/kg)	Mn content (mg/kg)	Zn content (mg/kg)	Cu content (mg/kg)
T ₁ : RDF (50:25:00 NPK kg/ha)	0.134	45.1	28.1	27.6 ^{de}	5.45	0.042	285.7	32.1	12.0	2.97
T ₂ : RDF + MM Grade V@ 20 kg/ha	0.137	47.1	27.3	28.4 ^{cd}	5.64	0.048	297.1	35.5	12.6	3.20
T ₃ : RDF+ MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	0.141	47.6	28.1	28.5 ^{bcd}	5.62	0.045	274.9	33.0	12.7	3.01
T ₄ : RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	0.138	49.2	28.8	30.6 ^a	5.87	0.049	288.3	33.6	13.5	3.08
T ₅ : RDF+ MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	0.139	50.5	30.4	28.8 ^{bcd}	5.77	0.049	322.7	34.2	13.1	3.18
T ₆ : RDF+ MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	0.140	51.9	27.9	29.4 ^{abc}	5.76	0.046	305.3	33.4	13.2	2.93
T ₇ : RDF + MM Grade V@ 20 kg/ha + MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	0.138	50.6	27.3	27.9 ^{cd}	5.87	0.047	274.5	33.2	12.6	3.14
T ₈ : RDF + MM Grade V@ 20 kg/ha + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	0.139	51.2	27.1	30.1 ^{ab}	5.60	0.048	296.9	32.4	12.8	2.91
T ₉ : RDF + MM Grade V@ 20 kg/ha + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	0.139	52.8	28.3	28.4 ^{cd}	5.75	0.048	298.2	33.3	13.4	3.02
T ₁₀ : RDF + MM Grade V@ 20 kg/ha + MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	0.139	46.0	27.8	28.5 ^{bcd}	5.73	0.049	273.3	32.7	12.6	3.20
T ₁₁ : RDF + 0.5% FeSO ₄ foliar spray at 20, 40 and 60 DAS	0.140	50.7	27.9	28.0 ^{cd}	5.81	0.051	295.6	33.6	12.7	3.00

T ₁₂ : RDF + 1.0% FeSO ₄ foliar spray at 20, 40 and 60 DAS	0.141	53.3	27.8	26.4 ^e	5.48	0.051	298.7	33.4	12.2	2.83
T ₁₃ : RDF + Micronutrient as per STV	0.138	54.9	28.9	27.8 ^{de}	5.67	0.048	276.3	33.3	11.9	2.95
S.Em. ±	0.002	2.16	1.41	0.48	0.11	0.002	12.07	0.74	0.45	0.09
CD at 5%	NS	NS	NS	Sig.	NS	NS	NS	NS	NS	NS
Y S.Em. ±	0.001	0.54	0.44	0.22	0.03	0.001	3.49	0.23	0.15	0.04
CD at 5%	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
Y x T S.Em. ±	0.002	1.96	1.57	0.81	0.13	0.002	12.58	1.25	0.53	0.16
CD at 5%	0.01	5.42	4.36	NS	NS	0.01	34.88	NS	1.48	NS
CV%	2.72	7.81	11.17	5.66	4.54	10.44	8.64	7.51	8.40	10.46

Treatment mean with the letter/letters in common are not significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance.

Table 4: Effect of the leaf analysis after one week of third foliar spray and active iron content of the plant at 30 DAS as influenced by different treatments in drilled paddy

Treatment	Leaf analysis				Active Fe (mg/kg) at 30 DAS
	Fe content (mg/kg)	Mn content (mg/kg)	Zn content (mg/kg)	Cu content (mg/kg)	
T ₁ : RDF (50:25:00 NPK kg/ha)	307.3	32.5	12.5 ^c	3.76	15.5 ^d
T ₂ : RDF + MM Grade V@ 20 kg/ha	311.6	34.6	13.0 ^{abc}	4.08	15.9 ^{cd}
T ₃ : RDF+ MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	302.2	33.9	13.0 ^{abc}	3.94	16.2 ^{cd}
T ₄ : RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	315.7	34.1	13.6 ^a	4.08	19.5 ^a
T ₅ : RDF+ MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	341.8	33.6	13.5 ^{ab}	4.04	17.4 ^{abcd}
T ₆ : RDF+ MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	329.9	33.9	13.5 ^{ab}	3.82	17.9 ^{abcd}
T ₇ : RDF + MM Grade V@ 20 kg/ha + MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	304.5	33.3	13.2 ^{ab}	3.96	16.6 ^{bcd}
T ₈ : RDF + MM Grade V@ 20 kg/ha + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	318.0	33.5	13.4 ^{ab}	3.82	18.8 ^{ab}
T ₉ : RDF + MM Grade V@ 20 kg/ha + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	327.5	33.4	13.2 ^{ab}	3.79	18.4 ^{abc}
T ₁₀ : RDF + MM Grade V@ 20 kg/ha + MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	307.3	33.1	13.3 ^{ab}	3.91	18.0 ^{abcd}
T ₁₁ : RDF + 0.5% FeSO ₄ foliar spray at 20, 40 and 60 DAS	326.4	33.7	12.8 ^{bc}	3.87	19.2 ^a
T ₁₂ : RDF + 1.0% FeSO ₄ foliar spray at 20, 40 and 60 DAS	328.7	34.3	12.4 ^c	3.71	19.5 ^a
T ₁₃ : RDF + Micronutrient as per STV	315.5	33.9	12.5 ^c	3.87	17.3 ^{abcd}
S.Em. ±	9.69	0.61	0.20	0.10	0.76
CD at 5%	NS	NS	Sig.	NS	Sig.
Y S.Em. ±	2.72	0.28	0.09	0.05	0.20
CD at 5%	Sig.	Sig.	Sig.	Sig.	Sig.
Y x T S.Em. ±	9.81	1.02	0.34	0.17	0.72
CD at 5%	27.18	NS	NS	NS	Sig.
CV%	6.16	6.08	5.19	8.89	8.19

Treatment mean with the letter/letters in common are not significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance.

Table 5: Economics as influenced by different treatments in drilled paddy

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Gross Realization (₹/ha)	Common Cost (₹/ha)	Treatment cost (₹/ha)	Total Cost of cultivation (₹/ha)	Net Realization (₹/ha)	B: C ratio
T ₁ : RDF (50:25:00 NPK kg/ha)	1036	2067	32094	25335	1935	27270	4824	1.18
T ₂ : RDF + MM Grade V@ 20 kg/ha	1244	2156	37070	25335	2735	28070	9000	1.32
T ₃ : RDF+ MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	1346	2355	40210	25335	8037	33372	6838	1.20
T ₄ : RDF + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	2016	3584	60480	25335	8997	34332	26148	1.76
T ₅ : RDF+ MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	1608	2870	48291	25335	8997	34332	13959	1.41
T ₆ : RDF+ MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	1284	2408	39084	25335	9357	34692	4392	1.13
T ₇ : RDF + MM Grade V@ 20 kg/ha + MM Grade I @ 1.0% foliar spray at 20, 40 and 60 DAS	1458	2597	43763	25335	8837	34172	9591	1.28
T ₈ : RDF + MM Grade V@ 20 kg/ha + MM Grade II @ 1.0% foliar spray at 20, 40 and 60 DAS	1405	2515	42228	25335	9797	35132	7096	1.20
T ₉ : RDF + MM Grade V@ 20 kg/ha + MM Grade III @ 1.0% foliar spray at 20, 40 and 60 DAS	1252	2108	37030	25335	9797	35132	1898	1.05
T ₁₀ : RDF + MM Grade V@ 20 kg/ha + MM Grade IV @ 1.0% foliar spray at 20, 40 and 60 DAS	1301	2345	39175	25335	10157	35492	3683	1.10
T ₁₁ : RDF + 0.5% FeSO ₄ foliar spray at 20, 40 and 60 DAS	1937	3471	58234	25335	4077	29412	28822	1.98
T ₁₂ : RDF + 1.0% FeSO ₄ foliar spray at 20, 40 and 60 DAS	1859	3254	55541	25335	4197	29532	26009	1.88
T ₁₃ : RDF + Micronutrient as per STV	1340	2720	41720	25335	2235	27570	14150	1.51
Price of Produce	Grain = ₹. 22/kg and Straw ₹.4.5/kg							

Conclusion

The treatments T₁₁ (RDF + 0.5% FeSO₄ foliar spray at 20, 40, and 60 DAS) and T₄ (RDF + MM Grade II @ 1.0% foliar spray at 20, 40, and 60 DAS) recorded the highest net return and benefit-cost ratio (BCR) compared to the other treatments. Under the Middle Gujarat Agro-Climatic Zone, for growing drilled paddy, it is recommended to apply either a 1.0% foliar spray (100 g per 10 litres of water) of the Government-notified multi-micronutrient mixture Grade II (Fe: 6.0%, Mn: 1.0, Zn: 4.0, Cu: 0.3 and B: 0.5%) or a 0.5% foliar spray of FeSO₄ (50 g per 10 litres of water), neutralized with 0.25% lime solution, at 20, 40 and 60 days after sowing. This should be accompanied by the application of 50 kg N/ha, comprising 25 kg N/ha and 25 kg P₂O₅/ha as a basal dose, followed by 25 kg N/ha as top dressing at 30 DAS.

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